Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(4) (2020) 215-218
DOI: 10.22060/ceej.2018.14919.5781

Experimental Investigation of Downstream Erosion Control of Stepped Spillways using Microsilica- Structured and Nano Materials

A. Ghaderi[1], R. Daneshfaraz[2,*] , R. Zaerkabeh[3], F. Ashkan[2]

[1] Department of Civil Engineering-Hydraulic Structures, University of Zanjan, Zanjan, Iran.
[2] Department of Engineering, University of Maragheh, Maragheh, Iran.
[3] Department of Civil Engineering, Sahand University of Technology, Tabriz, Iran.

ABSTRACT: Nano-structured materials are waterproof, and they can be used for the reduction of scouring in alluvial beds. In this research, the impact of clay additive and Nanomaterials and Silicafume to sedimentary bed materials of stepped spillway on controlling erosion and scouring are investigated as a Nonstructural solution. Firstly, the effect of the number of steps and flow regime on downstream scouring were studied. The results show that by increasing the number of steps on the same slop of chute and in a skimming flow regime on the steps, the depth and length of the scouring on the downstream of the stepped spillway increases. Then the impact of some injected additives to the sedimentary bed with the same number of steps and skimming flow regime was investigated. The results prove the positive effect of clay and its mixture with Nano-clay and Silicafume on the reduction of scouring length and depth reduction on the weir downstream. The best performance between three different compositions is related to the mixture of clay with Nano-clay and Silicafume in which they contributed in reduction profile of scoring by 48.74% and 46.38% respectively compared with the reference model. At the same time injection of clay to the sedimentary bed reduced the depth and length of scouring by 35.63% and 20.88% and injection of clay with Nanoclay reduced the depth and length of scouring by 41.41% and 37.75% respectively. These results can state the success of clay, Nano-clay, and Silicafume on the scouring control mechanism at downstream of hydraulic structures, especially in flood discharges.

Review History:

Received: 9/1/2018
Revised: 10/1/2018
Accepted: 10/7/2018
Available Online: 12/15/2018

Keywords:

Bed stabilization
Number of steps
Scouring in downstream of a stepped spillway
Silicafume
Nanoclay

1. Introduction

The importance of investigating of scouring phenomena at downstream of stepped spillway will appear when the scouring depth and exploit the bed material would be significant, as the structure's foundation appears. Many studies have been done on the scouring of hydraulic structure by researchers and different ways have been proposed to reduce scouring. However, using these methods cause some problems such as instability of the structure, disturbance of hydraulic flow conditions and river sediment and more important that disturbance of the river's environment. One of the solutions to control the downstream scouring of hydraulic structure is the stabilization of sedimentary beds that related to some factors such as sedimentary bed material, environmental conditions, the propose of stabilization, economic issues and environmental effects [1].

Nevertheless, economical additives are more effective and can be an alternative to other choices. Stabilization of a cohesionless sedimentary bed is available by mixing some clay soil under saturated conditions [2]. Also, nanostructured materials because of waterproof property can be effective in reducing scouring and erosion of sedimentary beds [3]. In this research, we have tried to find an appropriate way to reduce these problems by using materials compatible with nature and ecology of the river to reduce the downstream scour depth of the hydraulic structures through the addition of clay with Nanoclay, montmorillonite and micro silicon in bed materials at downstream of stepped spillway to reduce scouring dimensions in different discharges.

*Corresponding author's email: daneshfaraz@yahoo.com

2. Methods and Materials

2.1. Laboratory Equipment

The experiments of this research were carried out at the Hydraulic Laboratory of the University of Maragheh in a rectangular flume with length, width and height 5, 0.3, 0.25, respectively (Fig. 1).

Three types of the stepped spillway with 2, 3 and 4 step at height with the same chute angle, 45 have been chosen. Table 1 and Fig. 2 show geometric and hydraulic conditions in experiments and flow regime created on the stepped spillways, respectively.

2.2 Features of the sedimentary particles of the bed and the additives of the bed materials

In this study, a particle with an average diameter of 1.8 mm with a standard deviation of 1.262 was selected as bed material. In this case, the maximum amount of scouring is

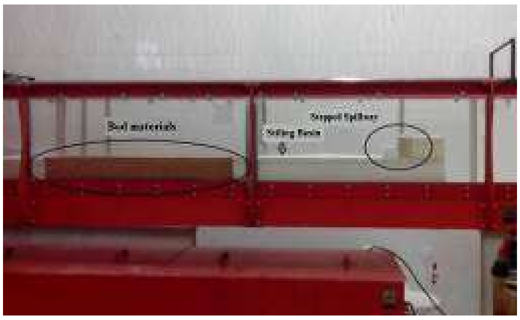

Fig.1. View of the stepped spillway, stilling basin, unstable bed in laboratory flume

Fig. 3. Additional materials to the movable bed of downstream of stepped spillway

Table 1. Specifications of geometric and hydraulic experimental parameters

Q (lit/s)	α°	h_c (cm)	L (cm)	h (cm)	L_d (cm)	H_s (cm)
3	45	2.1	3, 4, 6	3, 4, 6	80	12
7	45	3.8	3, 4, 6	3, 4, 6	80	12
11	45	5.1	3, 4, 6	3, 4, 6	80	12
15	45	6.3	3, 4, 6	3, 4, 6	80	12

Table 2. Specifications of models and different conditions of the experiments with the additional materials to the movable bed at the downstream of the stepped spillway

	Bed	Clay	Nano-clay	Micro-silica	Q (lit/s)
A	100%	-	-	-	3, 7, 11, 15
B	90%	10%	-	-	3, 7, 11, 15
C	89%	10%	1%	-	3, 7, 11, 15
D	89%	5%	1%	5%	3, 7, 11, 15

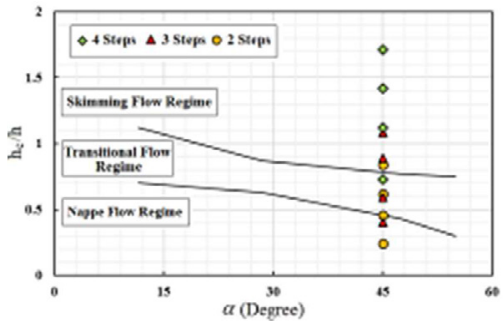

Fig. 2. Determine flow regimes created on the stepped spillway of this study

obtained and the repel is prevented. The fine-grained soil in the coarse aggregate bed, which accounts for 10% of the total, is achieved based on the WL and WP tests according to ASTM D4318-87 standard and the hydrometric test according to ASTM D421-58 standard. Nanoclay is added to the bed materials, Nanoclay Montmorillonite. In this study, the nanoclay was used as a wet method and an ultrasonic machine was used for uniform distribution of nanoclay in a mixture. The microsilica used in powder was mixed with clay and the mixture was added to the sediment bed.

3. Results and Discussion

3.1 The effect of the number of steps on downstream scouring in the control test

According to studying [4], the behavior of the nappe flow regime with more energy dissipation in the flumes is

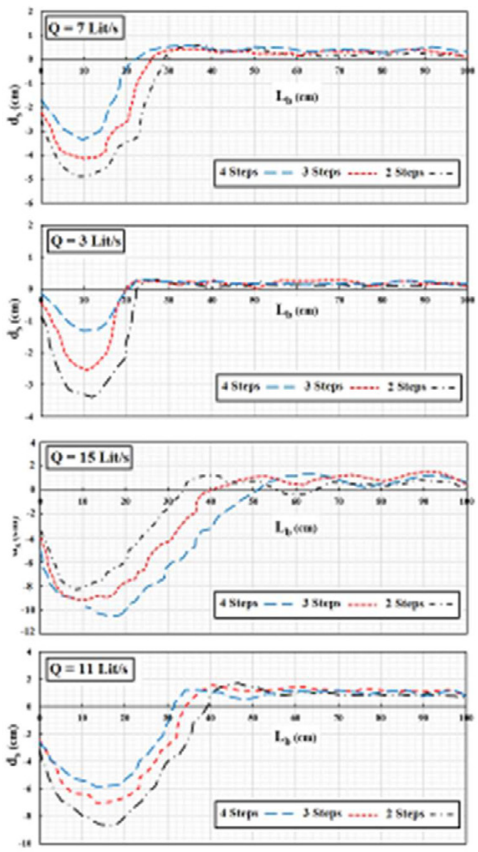

Fig. 4. The downstream scouring hole profile for different number of steps and different discharges

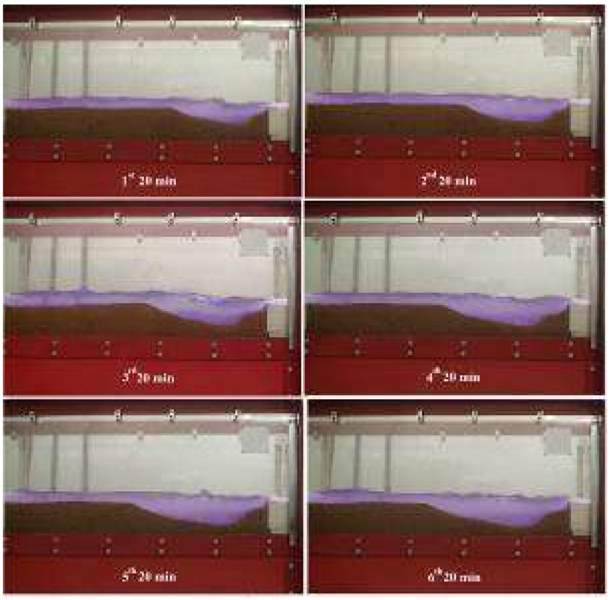

Fig. 5. Longitudinal scouring profiles with steps of 3cm height and discharge of 7 lit/s

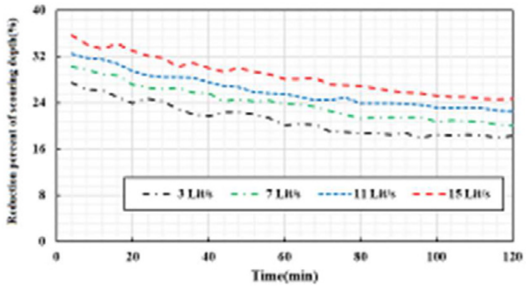

Fig. 6. Reduction percent of scouring depth due to the addition of clay with Nano-clay and Micro-silica

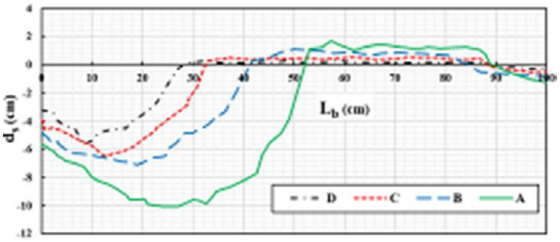

Fig. 7. Comparison of longitudinal scouring profiles with the discharge of 15 lit/s after 2 hours of the experiment

more efficient than the Skimming flow regime. So it can be predicted that the more amount of energy dissipation caused by the energy dissipator is effective in decreasing the amount of downstream scouring.

It was observed that the same under the same condition of flow, the amount of scouring increases with number of steps and a decrease in the hight of the steps. As the achieved results show less amount of scouring in a stepped spillway with a few steps.and this result shows more energy dissipation in stepped spillways with higher steps (stepped spillways with 2 steps and steps with 6cm hight). So this research is in good agreement with the ones done by the past researchers [4, 5].Also in a comparison with the skimming and transition flow regimes the least depth of scouring is observed for the nappe flow regime. Hence, it is concluded that this research confirms the experimental results achieved by the previous researchers

3.2 The effect of using micro silica and nanomaterials on the depth and length of downstream scouring in a stepped spillway

As the most amount of scouring profiles taken from the downstream of the spillway is related to stepped spillways with4 steps and the hight of 3 cm and in a skimming flow regime, the effect of using clay and Microsilica and Nanomaterials in downstream scouring of a stepped spillway and the skimming flow regime will be studied.

Fig. 6 shows that the highest percentage of reduction in-depth and scour length compared to other flows occurred at a rate of 15 liters per second. Also, the positive effect of clay and Nanoclay composition with the addition of 5wt. % of sedimentary bed of Microsilicon to it is clear in decreasing the depth and scour length, especially in the discharge, up to 48.44 and 46.38% respectively. In the fourth experiment, the reduction of scour depth was 48.44% at the first time of the experiment and 40.83% at the last time of extracting the laboratory data (2 hours).

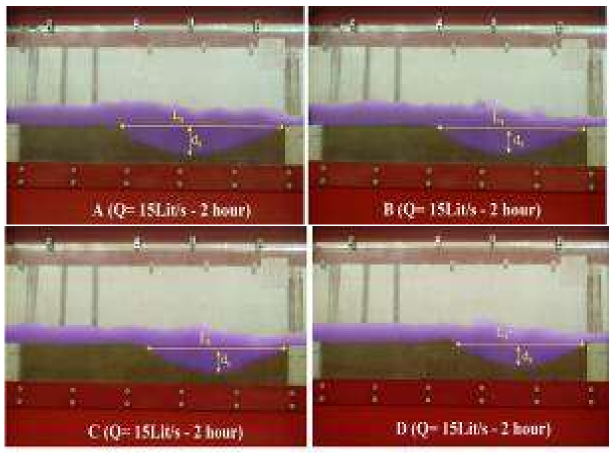

Fig. 8. A view of longitudinal scouring profiles of a stepped spillway for 4 different conditions of experiments

In Fig. 7, in the second to fourth experiments and at the last extracting time (2 hours), the scour depth decreased from about 10.80 cm to 7. 13, 6.49, and 5.67 cm, respectively. The scour length at the downstream of the stepped spillway is also limited from 52.94 cm to 41.89, 32.95 and 38.88 cm in the second to fourth experiments. The greatest effect on bed stabilization is due to the composition of clay with Nanoclay and Microsilica.

In Fig. 8, the positive effect of clay and its composition with Nanoclay and Microsilica can be clearly seen in reducing the depth and length of scouring profiles.

4. Conclusion

The most important results are demonstrated below:

· The greatest amount of scouring profiles occurs in the downstream of the stepped spillway with a greater number of steps and shorter steps, and in the skimming flow regime in the same slope of the overflow spillway's chute.

· The effect of additive injected into the unsTable bed of the downstream of the spillway on the number of steps of the stepped spillway and skimming flow regime indicates the positive effect of clay and its composition with Nanoclay and Microsilica to improve and reduce the depth and length of scouring, especially in the early stages of extracting at the downstream of the stepped spillway.

· By increasing the discharge, the highest percentage of reduction in depth and length of scouring occurred. The maximum scouring depth from about 11.08 cm in the first experiment (control), with the addition of clay and clay composition with Montmorelonite Nanoclay and Microsilica, Respectively, decreased to 7.7, 6.49, and 5.67 cm (35.63, 41.41 and 48.74% respectively).

· The positive effect of clay and its composition with Nanoclay and Microsilica were also positive in reducing the scouring pit size so that the scouring length decreased from 52.94 to 38.88 cm (46.38%).

References

[1] Tingle, J. 2004, "Emulsion polymers for soil stabilization". *in Proceedings of the FAA Worldwide Airport Technology Transfer Conference*, Atlantic City, New Jersey, USA.

[2] Zomorodian, S.M.A., Arab, M., and Zolghadr, M., 2017. "Effect of Clay Content Percentage and Compaction Energy on Pier Bridge Scour in Erosive Bed and in the vicinity of abutment". *Modares Civil Engineering Journal*, 17(2): p. 167-177 (in Persian).

[3] Ghasemi, E., Zahiri, A., Meftah, M., and Dehghani, A.A. 2017, "Controlling Local Scouring around Bridge Pier using Nano-Structured Material". *Water and Soil Science*, 27(3): p. 79-91 (in Persian).

[4] Chanson, H., 1994. "Comparison of energy dissipation between nappe and skimming flow regimes on stepped chutes". *Journal of hydraulic research*, 32(2): p. 213-218.

[5] Ghaderi, A., 2016. "The Experimental investigation of the effect of Labyrinth Weir geometric parameters with energy dissipater on the scour of downstream". *M.Sc. Thesis*, University of Maragheh, Maragheh, Iran (in Persian).

HOW TO CITE THIS ARTICLE

A. Ghaderi, R. Daneshfaraz, R. Zaerkabeh, F. Ashkan, Experimental Investigation of Downstream Erosion Control of Stepped Spillways using Microsilica- Structured and Nano Materials, Amirkabir J. Civil Eng., 52(4) (2020) 215-218.

DOI: 10.22060/ceej.2018.14919.5781